

ELECTRONIC FUNDAMENTALS

EXPERIMENT LESSON 8

RESISTANCE MEASUREMENTS



RCA INSTITUTES, INC.

A SERVICE OF RADIO CORPORATION OF AMERICA

HOME STUDY SCHOOL

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Experiment Lesson 8

OBJECT

1. To complete the assembly of the ohmmeter section of your multimeter.
2. To use the ohmmeter ranges of your multimeter to measure resistance.
3. By measuring resistances in series and in parallel, to verify the theory studied in Theory Lesson 8.

PREPARATION

Examine the schematic diagram shown in Fig. 8-1 to see the electrical connections to be made in the first part of this lesson. As in previous lessons, the work already done is shown by light lines and the work to be done in this lesson is shown by heavy dark lines. In this way, you can see how the wiring you are going to do fits in with the wiring done in previous lessons.

PART ONE

EQUIPMENT NEEDED

- Multimeter
- Two battery clips
- One 1.5-volt C-type dry cell
- One 6-volt battery
- One 110 k-ohm resistor
- Soldering iron, cloth, and solder
- Long-nose pliers
- Two each of 6-32 x 3/8 inch screws and nuts

- 9. One medium-blade screwdriver
- 10. Cutting pliers
- 11. Hook-up wire

JOB 8-1

To mount the battery clips in the meter box, as shown in Fig. 8-2 and 8-3.

Note: Before you try to mount either battery clip, look carefully at the battery clips from your kit. Notice that one is smaller than the other. It is made to fit the small 1.5-volt C cell, while the other clip is made for the 6-volt battery. Compare these clips with those shown in Fig. 8-3; note where each clip is placed when properly mounted. Then make sure that you mount each clip on the side on which it is supposed to go.

Procedure.

Step 1. Insert 6-32 x 3/8-inch screw from the outside of the box into the hole shown in Fig. 8-2, pushing it toward the inside of the box as far as it will go. Hold it in place with your finger.

Step 2. Holding one of the battery clips in the direction shown, mount the battery clip to the side of the meter case, using the screw that you are holding with your finger, the hole in the battery clip, and one 6/32 nut. Hold the nut in place with your long-nose pliers as you tighten the screw with your screwdriver.

Step 3. Mount the second battery clip to the other side of the meter box, as shown in Fig. 8-3.

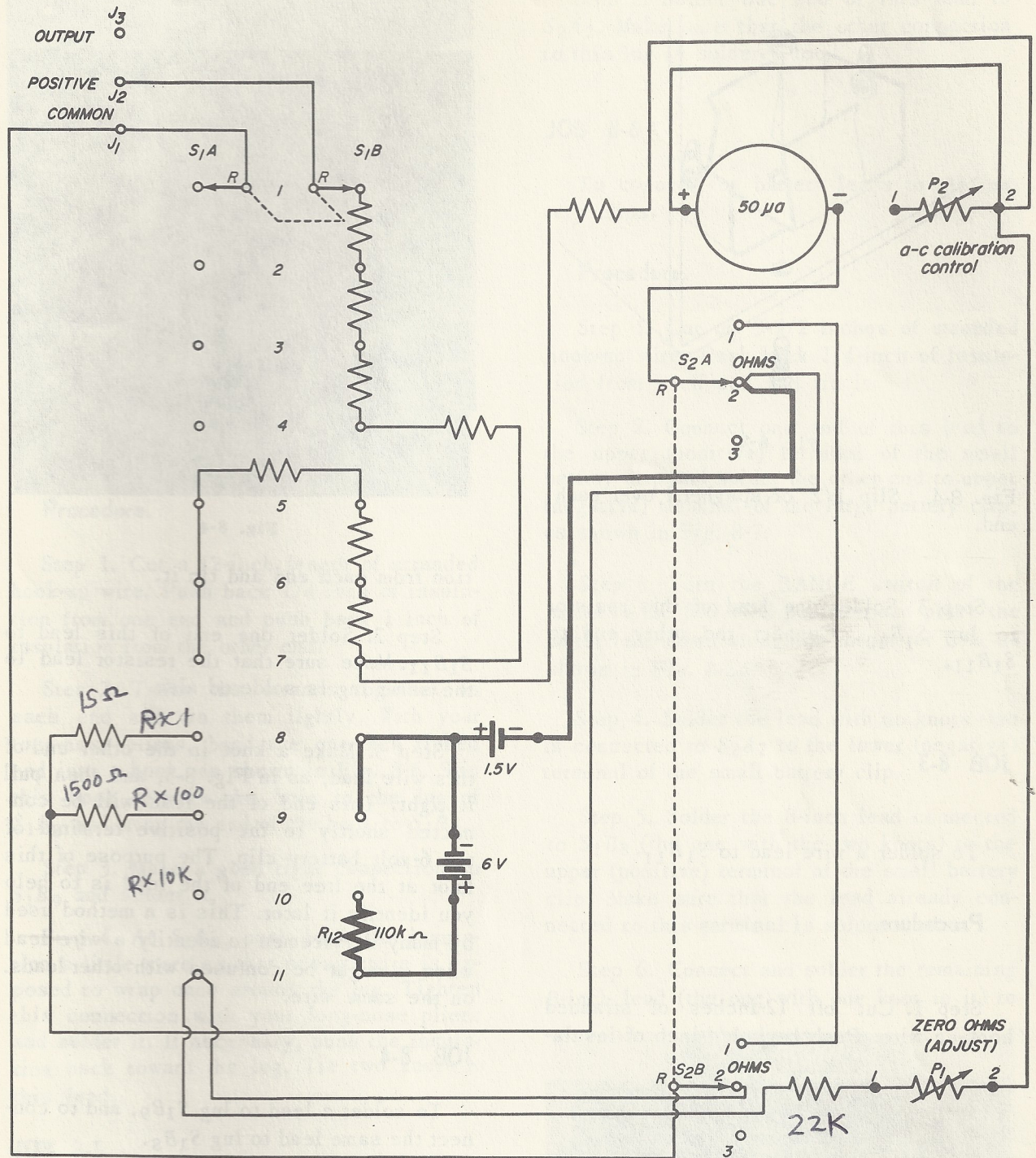


Fig. 8-1

JOB 8-2

To mount 110 k-ohm resistor R_{12} .

Procedure.

Step 1. Prepare the 110 k-ohm resistor

R_{12} by removing 3/4-inch of wire from each end with your cutting pliers. If necessary, clean the resistor leads lightly with fine sandpaper. Do not remove the tinning.

Step 2. With your long-nose pliers, bend the resistor leads into the shape shown in

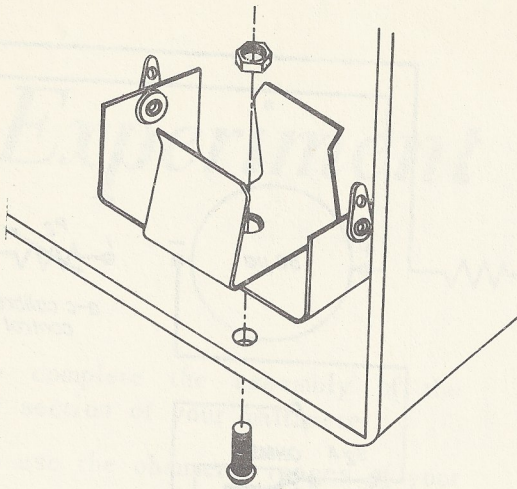


Fig. 8-2

Fig. 8-4. Slip $1/2$ " of spaghetti over each end.

Step 3. Solder one lead of this resistor to lug S_1B_{10} . Connect the other end to S_1B_{11} .

JOB 8-3

To solder a wire lead to S_1B_{11} .

Procedure.

Step 1. Cut off 12-inches of stranded hook-up wire. Push back $1/4$ -inch of insula-

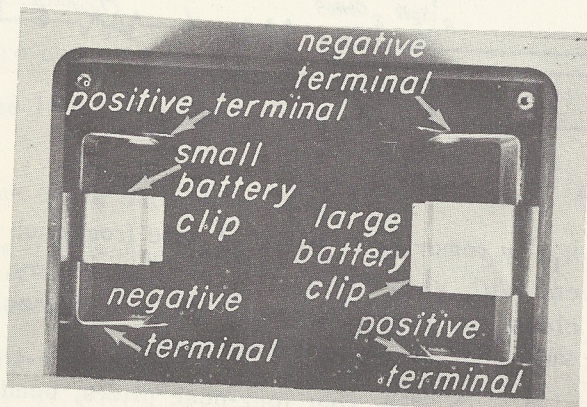


Fig. 8-3

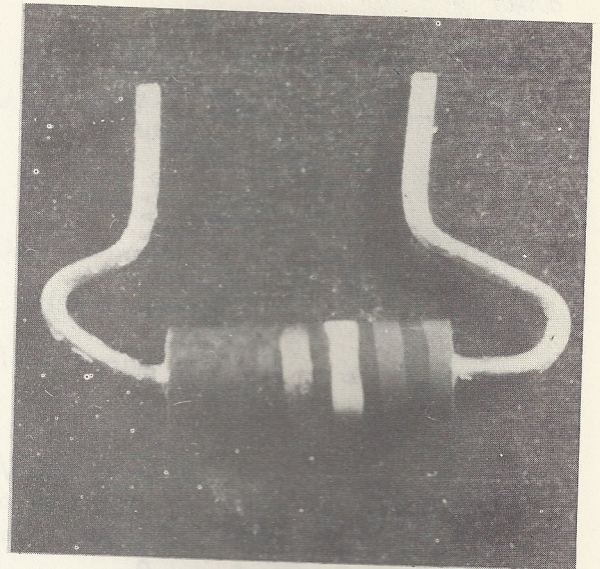


Fig. 8-4

tion from each end and tin it.

Step 2. Solder one end of this lead to S_1B_{11} . Make sure that the resistor lead to the same lug is soldered also.

Step 3. Make a knot in the other end of this wire lead, as in Fig. 8-5, and then pull it tight. This end of the lead will be connected shortly to the positive terminal of the 6-volt battery clip. The purpose of this knot at the free end of the lead is to help you identify it later. This is a method used by many servicemen to identify a wire lead when it might be confused with other leads on the same wire.

JOB 8-4

To solder a lead to lug S_1B_9 , and to connect the same lead to lug S_1B_8 .

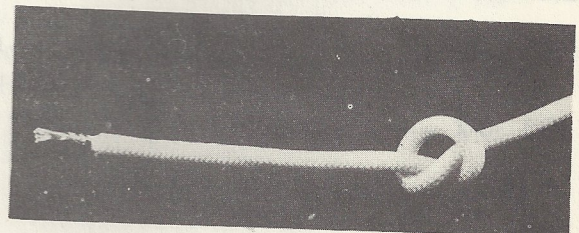


Fig. 8-5

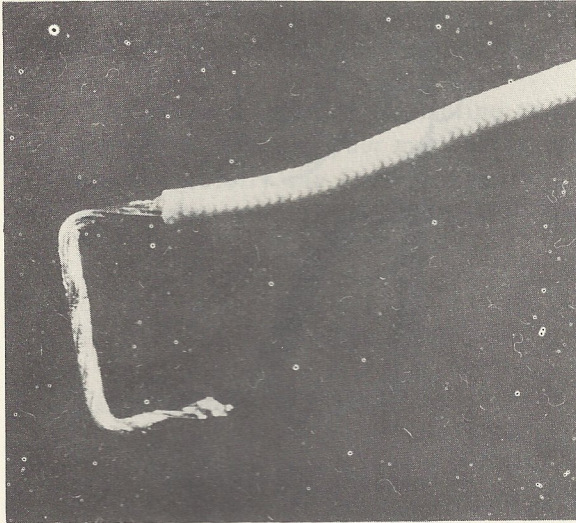


Fig. 8-6

Procedure.

Step 1. Cut a 12-inch length of stranded hook-up wire. Push back 1/4 inch of insulation from one end and push back 1 inch of insulation from the other end.

Step 2. Twist the strands together on each end and tin them lightly. With your long-nose pliers, bend the one-inch tinned end into a hook, as shown in Fig. 8-6. Slip this hook through the hole in the lug of S_1B_8 and bring the end of the hook to S_1B_9 .

Step 3. Make a good tight connection on S_1B_9 and solder it.

Step 4. At S_1B_8 , push back the insulation a little more so that enough wire is exposed to wrap once around the lug. Tighten this connection with your long-nose pliers and solder it. If necessary, push the insulation back toward the lug. Tie two knots in this lead.

JOB 8-5

To solder a lead to terminal S_2A_2 .

Procedure.

Step 1. Cut off one 10-inch length of stranded hook-up wire. Push back 1/4 inch of insulation from each end. Twist each end and tin it slightly.

Step 2. Solder one end of this lead to S_2A_2 . Make sure that the other connection to this lug is soldered too.

JOB 8-6

To connect the battery leads to the battery clips.

Procedure.

Step 1. Cut off 3-1/2 inches of stranded hook-up wire. Push back 1/4-inch of insulation from each end and tin it.

Step 2. Connect one end of this lead to the upper (positive) terminal of the small battery clip and solder the other end to upper (negative) terminal of the large battery clip, as shown in Fig. 8-7.

Step 3. Turn the RANGE switch of the meter to the 500 VDC position and place the meter face down alongside the meter box, as shown in Fig. 8-8a.

Step 4. Solder the lead with no knots that is connected to S_2A_2 to the lower (negative) terminal of the small battery clip.

Step 5. Solder the 8-inch lead connected to S_1B_8 (the one with the two knots) to the upper (positive) terminal of the small battery clip. Make sure that the lead already connected to this terminal is soldered also.

Step 6. Connect and solder the remaining 8-inch lead (the one with one knot in it) to

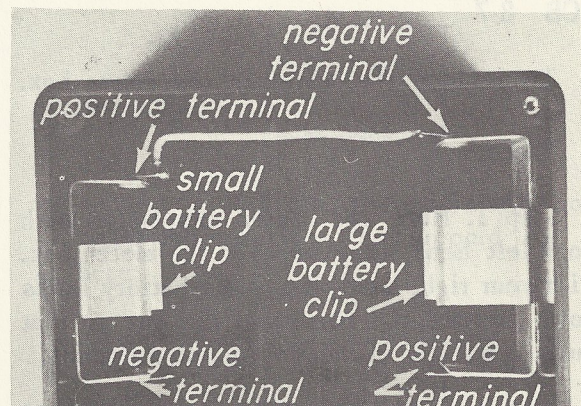
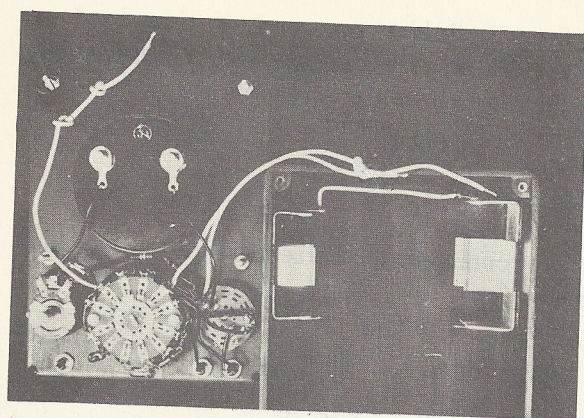
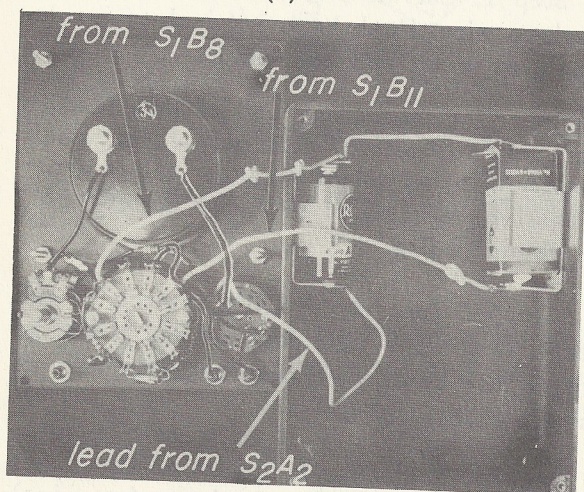


Fig. 8-7



(a)



(b)

Fig. 8-8

the lower (positive) terminal of the large battery clip.

Step 7. Place the 1.5-volt cell and the 6-volt battery in the clips, as shown in Fig. 8-8b.

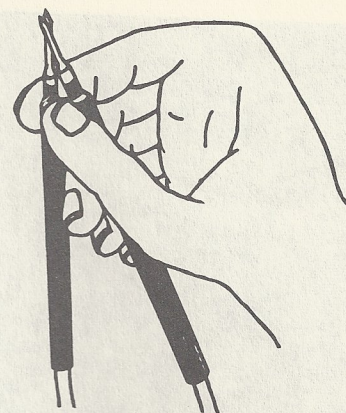
JOB 8-7

To replace the meter in the meter box.

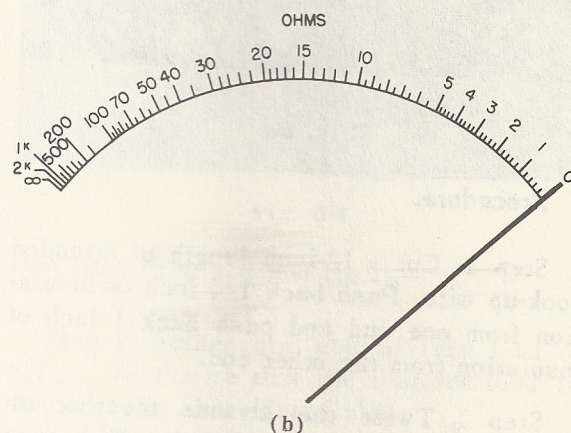
Procedure.

Step 1. Hold the meter assembly, with your left hand, face up over the meter box. With your right hand, dress the battery leads down toward the bottom of the box so that they do not get in the way of the switches.

Step 2. Place the meter assembly face up in the case and fasten the panel at the four corners with the four panel screws.



(a)



(b)

Fig. 8-9

JOB 8-8

To prepare the multimeter for use as an ohmmeter on the R x 1 scale.

Procedure.

Step 1. Turn the FUNCTION switch to the OHMS marker line.

Step 2. Turn the RANGE switch to the R x 1 marker line.

Step 3. Place the black test lead phone tip in the black (negative) pin jack and the positive test lead phone tip in the red (+) pin jack.

Step 4. Zero the meter. This is done by holding the tips of the positive and negative test prods together between your left thumb and forefinger, as shown in Fig. 8-9a, and adjusting the ZERO OHMS knob until the meter needle rests directly over the zero calibration line on the OHMS scale, as shown in Fig. 8-9b.

Your meter is now ready to measure resistance directly in ohms on the R x 1 range.

Caution: Before attempting to use the ohmmeter ranges of your multimeter, read and study carefully the instructions for the use of an ohmmeter given in Service Practices 7.

PART TWO

EQUIPMENT NEEDED

Multimeter

Soldering iron, cloth, and solder

Long-nose pliers

The resistor board assembled in Experiment Lesson 1

INFORMATION

Even though you have carefully studied the instructions for using an ohmmeter given in Service Practices 7, there are a few instructions that must be repeated here.

1. Never connect the ohmmeter ranges of your multimeter to any source of electric power, such as a dry cell, battery, generator, or your home or shop power lines.

2. Always be sure that all sources of electricity are disconnected from a piece of equipment before using your ohmmeter ranges.

3. For the most accurate readings, use the ohmmeter range that gives you a reading in the center path of the meter scale, as shown in Fig. 8-10. When measuring very-low or very-high resistance values, it is not

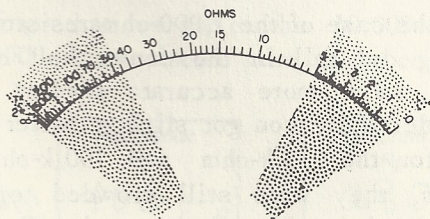


Fig. 8-10

always possible to get a reading in this center half of the scale.

4. For accurate readings, be sure that the meter is zeroed for the ohmmeter scale you intend using.

EXPERIMENT 8-1

To use the ohmmeter to measure the resistor breadboard.

Procedure.

Step 1. Your ohmmeter should be ready to measure resistance on the R x 1 range. Place one test prod at one end of the 100-ohm resistor and the other test prod at the other end of the same resistor. Read the value of resistance on the ohmmeter scale. The meter needle should come to rest near the 100-calibration line on the top (ohmmeter) scale. Because you are using the R x 1 scale, you multiply this reading by 1, which gives you a value of 100 ohms.

Step 2. In the same way, measure the resistance of the 220-ohm resistor. Record the value here:

220

Step 3. Measure the resistance of the 330-ohm resistor. Record the value here:

330

Step 4. Measure the resistance of the 1,000-ohm resistor, and record the value here:

1k

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Step 5. Measure the resistance of the 10,000-ohm resistor and 100,000-ohm resistors. Note the position of the meter needle in each case, but do not record any value.

Discussion. In all the readings that you have just made, the needle should have come to rest at the left end of the meter dial. In the case of the first four resistors, the readings were probably close to the values shown by the color code. In the case of the last two resistors (10 k-ohm and 100 k-ohm), the meter needle hardly moved, and there was no way by which you could tell one resistance value from the other.

You have been told in this lesson and in Service Practices 7 that the ohmmeter is most accurate when the reading falls in the center half of the scale. None of the readings that you made fall in this portion of the scale. For this reason, you will next try the R x 100 range. Readings on this range are multiplied by 100.

Preparation. Turn the RANGE switch to the R x 100 marker line. Zero the meter by holding the tip of the test prods together as you adjust the ZERO OHMS knob until the meter needle is directly over the zero calibration line on the OHM scale.

Step 6. Measure the resistance of the 100-ohm resistor and record the value here:

120Ω

Step 7. Measure the resistance of the 220-ohm resistor and record the value here:

280Ω

Step 8. Measure the resistance of the 330-ohm resistor and record the value here:

420Ω

Step 9. Measure the resistance of the 1,000-ohm resistor and record the value here:

1160Ω

Step 10. Measure the resistance of the 10,000-ohm resistor and record the value here:

12,000

Step 11. Measure the resistance of the 100,000-ohm resistor and record the value here:

100,000+

Discussion. In the measurements just made, for the first three readings, the needle came to rest at the right-hand side of the meter dial. While you probably got better readings than you did on the R x 1 scale, they were still not in the center half of the scale. However, there are times when the measurements you make cannot fall in that part of the scale. In such cases, you use whichever scale gives you the better reading.

In the case of the 1,000-ohm resistor, the reading did fall in the center half of the scale, so a more accurate reading was possible. While you got slightly better readings for the 10 k-ohm and 100 k-ohm resistors, they were still crowded together near the left side of the scale. For that reason, you will now repeat these measurements on the R x 10 k range. On this range,

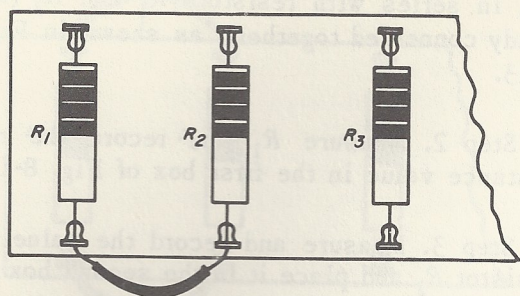


Fig. 8-11

all readings are multiplied by 10,000.

Preparation. Turn the RANGE switch to the R x 10 K marker line and zero adjust as before.

Step 12. Measure the resistance of each of the first 4 resistors (100-ohm, 220-ohm, 330-ohm and 1,000-ohm resistors). Do not record these values but notice the position of the meter needle in each case.

Step 13. Measure the resistance of the 10,000-ohm resistor and record it here:

10,000+

Step 14. Measure the resistance of the 100,000-ohm resistor and record it here:

100,500

Discussion. The four readings that you took in Step 12 were of very little value because they were all crowded together at the right-hand side of the scale. However, the readings that you got on the 10,000-ohm and 100,000-ohm resistors were in the center

half of the scale. As a result, they were more accurate and more useful.

PART THREE

EQUIPMENT NEEDED

Same as for Part One

Short lengths of hook-up wire used on the breadboard in Experiment Lesson 7

INFORMATION

In the experiments in Part 2, you measured the values of individual resistors and learned how to use the three ranges of your ohmmeter. In Part 3, you will combine resistors in series and in parallel, measure the total resistance in each case, and compare your measurements with the resistance values found by figuring them according to the rules studied in Theory Lesson 8. In any figuring that you do in this part of the lesson, use only the measured value of resistance for each resistor and not the rated value shown by the color code. In this way, your figuring will come much closer to the measured value of each combination of resistors.

To connect resistors together on your resistor board, use the small pieces of bare tinned wire that you used in Experiment Lesson 7. If you have thrown these wires away, it will be necessary for you to cut new ones.

EXPERIMENT 8-2

To connect two resistors in series and to measure the total resistance.

Procedure.

Step 1. Connect the 100-ohm resistor R_1 in series with the 220-ohm resistor R_2 , as shown in Fig. 8-11.

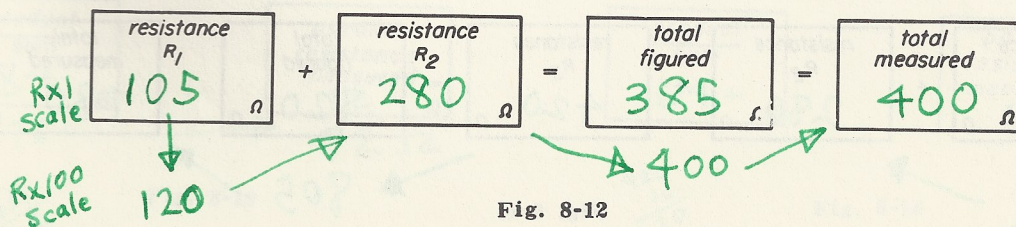


Fig. 8-12

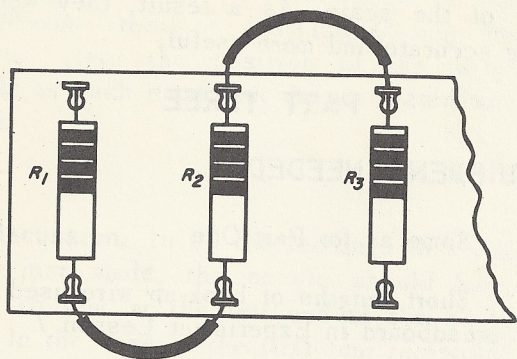


Fig. 8-13

Step 2. Measure, and record in the first box of Fig. 8-12, the resistance of R_1 .

Step 3. Measure, and record in the second box of Fig. 8-12, the resistance of R_2 .

Note: According to Theory Lesson 8, the total resistance of two or more resistors connected in series is equal to the sum of the individual resistances.

Step 4. Add the resistances of R_1 and R_2 together and put the answer in the third box of Fig. 8-12.

Step 5. With the ohmmeter, measure the resistance of R_1 and R_2 in series by placing one prod on each of the free ends of resistor R_1 and resistor R_2 . Record this value in the fourth box of Fig. 8-12. If this has been done correctly, the value recorded in the third box should equal the value recorded in the fourth box.

EXPERIMENT 8-3

To connect three resistors in series and measure the total resistance and to compare this value with the calculated value.

Procedure.

Step 1. Connect the 330-ohm resistor,

R_3 , in series with resistors R_1 and R_2 (already connected together), as shown in Fig. 8-13.

Step 2. Measure R_1 and record the resistance value in the first box of Fig. 8-14.

Step 3. Measure and record the value of resistor R_2 and place it in the second box of Fig. 8-14.

Step 4. Measure and record the value of R_3 in the third box of Fig. 8-14.

Step 5. Add these three values together and record the sum in the fourth box of Fig. 8-14.

Step 6. Measure the total resistance of R_1 , R_2 , and R_3 in series by placing one prod on the free end of R_1 and the other on the free end of R_3 . Record this value in the fifth box of Fig. 8-14. The value of resistance recorded in the fourth box should equal the value of resistance recorded in the fifth box. They may vary a little, of course.

EXPERIMENT 8-4

To connect two resistors in parallel, to measure their resistance, and to compare this value with the calculated value.

Procedure.

Step 1. Disconnect from R_3 the lead that connects it to R_2 . Then connect the free end of this lead to R_1 , as shown in Fig. 8-15.

Step 2. Record, in the first box of Fig. 8-16, the resistance of R_1 , as you measured it in Experiment 8-3.

Step 3. Record, in the second box of Fig. 8-16, the resistance of R_2 as you measured it in Experiment 8-3.

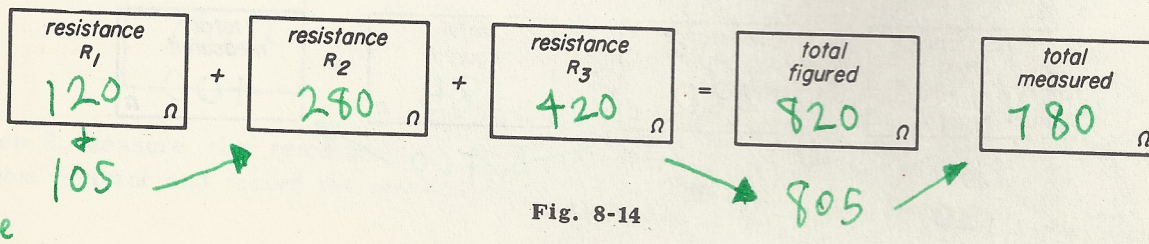


Fig. 8-14

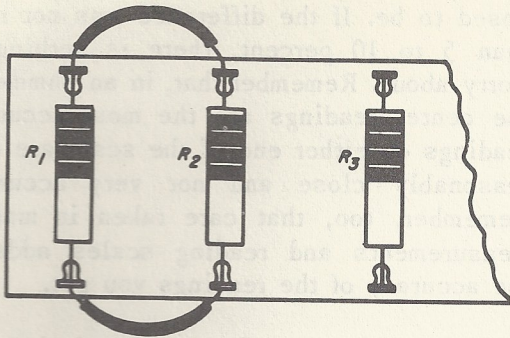


Fig. 8-15

Note: According to Theory Lesson 8, the total resistance of any two resistors connected in parallel is equal to their product divided by their sum.

Step 4. Calculate the value of R_1 and R_2 in parallel in the way described above. Record this value in the third box of Fig. 8-16.

Step 5. Measure the value of the resistance of R_1 and R_2 in parallel by placing one prod on one end of R_1 and the other prod on the other end of R_1 . Naturally, you could also measure this resistance by placing one prod on one end of R_2 and the other prod on the other end of R_2 . In either case, you would get the same answer. Record this measurement in the fourth box of Fig. 8-16. The value of the resistance in the third box should equal that in the fourth box. If there is a great difference between the two values, check the figuring you did to get the calculated value.

EXPERIMENT 8-5

To connect three resistors in parallel, to measure the total resistance, and to com-

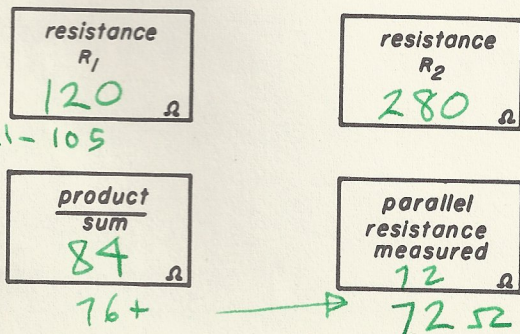


Fig. 8-16

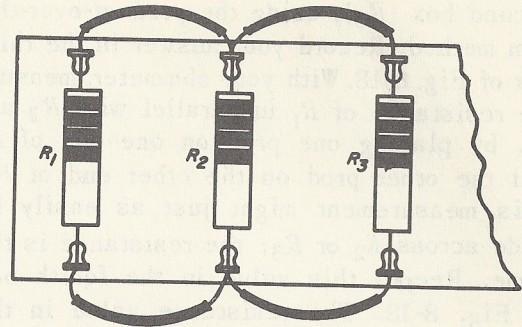


Fig. 8-17

pare the value with the calculated value.

Procedure.

Step 1. Connect resistor R_3 in parallel with resistors R_1 and R_2 , as shown in Fig. 8-17.

Note When three resistors are connected in parallel, the total resistance may be calculated by using the product-over-the-sum method. Just do the work in steps. For example, to find the total resistance of R_1 , R_2 , and R_3 in parallel, we may first calculate the resistance of two of them in parallel and use this calculated value in parallel with the third resistor. You have already calculated the resistance of R_1 and R_2 in parallel, so record this value in the first box of Fig. 8-18.

Step 2. Record, in box 2 of Fig. 8-18, the measured value of resistance of R_3 as found in Experiment 8-3.

Step 3. Calculate the total resistance of the combination of the resistance in the first box in parallel with the resistance in the

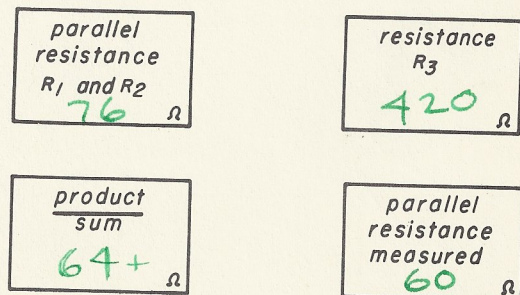


Fig. 8-18

$385 \overline{) 29400}$
 $76 \times$
 280
 105
 2800
 2695
 1050
 1050
 0

400
 280
 120
 5600
 2800
 33600

420
 76
 2920
 2920
 31920

$64 +$
 $496 \overline{) 31920}$
 2916
 2160

second box (R_3), using the product-over-the-sum method. Record your answer in the third box of Fig. 8-18. With your ohmmeter, measure the resistance of R_1 in parallel with R_2 and R_3 , by placing one prod on one end of R_1 and the other prod on the other end of R_1 . This measurement might just as easily be made across R_2 or R_3 ; the resistance is the same. Record this value in the fourth box of Fig. 8-18. The resistance value in the third box should equal that of the fourth box. If there is a great difference between these values, check your calculation.

Discussion. Let's see what you learned in the second and third parts of this Experiment Lesson. In Experiment 8-2, you found that the resistance of R_1 and R_2 in series, as measured, is equal to R_1 added to R_2 .

In Experiment 8-3, you found that R_1 , R_2 , and R_3 in series equal, when measured, $R_1 + R_2 + R_3$. You might have gone on adding resistors in series only to find that the total resistance is still equal to the sum of the individual resistors. No doubt you found some places where the figures were not exactly equal, even though they were sup-

posed to be. If the difference was not more than 5 to 10 percent, there is nothing to worry about. Remember that, in an ohmmeter, the center readings are the most accurate; readings on either end of the scale are only reasonably close and not very accurate. Remember, too, that care taken in making measurements and reading scales adds to the accuracy of the readings you get.

In Experiment 8-4, you found that the measured resistance of two resistors connected in parallel was about equal to the calculated value. You probably found that the product of two resistors divided by their sum is a pretty good way to find the total resistance of two resistors in parallel and you probably found that this method works equally well when there are three or more resistors in parallel. What is more important is that you have proved in this, and in the last lesson, that many of the things you learned in the theory lessons are true — because you are actually able to measure and see for yourself. If you found the last two lessons interesting, you will find the following Experiment Lessons even more interesting. What is more, you will soon know much more about the circuits of your multimeter.

